Understory biomass and nutrients 2 years after timber harvest in northern Minnesota

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Adjacent areas within a 60-year-old *Abies balsamea* (L.) Mill. – *Betula papyrifera* Marsh. stand in northern Minnesota, U.S.A., were clear-cut by whole-tree logging or tree-length logging followed by prescribed burning. Two years after harvest, understory biomass and nutrients were sampled on these sites and on an adjoining uncut control. All logged sites had significantly more total aboveground understory biomass than the control. However, biomass of woody species on the tree-length logged burn area did not differ from the control site. Because of the greater biomass on harvested sites, nutrient accumulations (N, P, K, Ca, Mg) by the understory were greater, with about 75% of these extra nutrients in herbs and shrubs. Although the quantity of nutrients in the understory is less than that removed with the overstory, it is important in maintaining the nutritional integrity of the system because it serves as a sink for available nutrients.

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Des surfaces adjacentes dans un peuplement *Abies balsamea* (L.) Mill. – *Betula papyrifera* Marsh. de 60 ans du nord du Minnesota furent coupées à blanc selon la méthode de l'arbre entier ou de l'arbre en longueur suivies d'une prescription de brûlage. Deux ans après la coupe la biomasse du sous-bois et les nutrients furent échantillonnées sur ces sites et sur une parcelle témoin. Tous les sites exploités avaient une biomasse au-dessus du sol plus importante que la parcelle témoin. Cependant, la biomasse des espèces ligneuses sur les sites exploités selon la méthode de l'arbre en longueur et brulés ne différait pas de la parcelle témoin. En raison d'un biomasse plus importante sur les sites coupés, les accumulation de nutrients (N, P, K, Ca, Mg) dans le sous-bois étaient supérieurs avec environ 75% de ces nutrients supplémentaires provenant des herbes et des arbustes. Même si la quantité de nutrients dans le sous-bois est moindre que celle obtenue avec l'étage supérieur elle est importante dans le maintient de l'intégrité de la nutrition du système parce qu'elle sert de drain pour les nutrients disponibles.

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Introduction

Two common disturbances in forest ecosystems are clear-cutting and fire. These are important ecologically because they affect species composition and growth, and future productivity. The question of future productivity has become of greater concern in recent years, and utilization standards have changed. As a result, technological innovations have made it possible to use small material and parts of trees besides the bole, such as bark, branches, and roots. Therefore, much more of the standing-crop biomass and, consequently, more of the accumulated nutrients, are removed during harvest operations.

This study assesses the effects of clear-cutting and clear-cutting followed by prescribed burning on the productivity and nutrient status of the understory of a mixed stand of balsam fir – paper birch (*Abies balsamea* (L.) Mill. – *Betula papyrifera* Marsh.) in northern Minnesota. The importance of the understory in forest ecosystems for nutrient cycling and maintenance of site productivity after overstory removal has been demonstrated at Hubbard Brook (Marks and Bormann 1972; Bormann *et al.* 1974; Marks 1974). Tappeiner and Alm (1975) have shown that the understory can significantly affect nutrient cycling in forest stands in the region of this study by increasing nutrient quantities in litter fall.

Study area

The study was done on the University of Minnesota's Cloquet Forestry Center, located about 17 km southwest of Duluth, MN (latitude 46°43′ N, longitude 92°29′ W). This area lies within Kuhler's (1964) Great Lakes spruce–fir forest vegetation zone. The climate is subhumid continental, with long, cold winters and short, warm summers. The average temperature is −13°C for January and 19°C for August (Baker and Strub 1965). The average yearly precipitation is 73 cm

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TABLE 1. Biomass and nutrients (in kilograms per hectare) of the understory two growing seasons after treatment

Component	Treatment		
	Whole-tree logged	Tree-length logged and burned	Uncut control
Biomass			
Herbaceous spp.	1969 (293)*a*	2081 (240)*a*	622 (85)*b*
Woody spp.	2212 (581)*a*	523 (298)*b*	320 (108)*b*
Total	4181 (539)*a*	2604 (352)*a*	942 (136)*b*
Nitrogen			
Herbaceous spp.	25.0 (3.3)*a*	28.8 (2.6)*a*	8.9 (1.1)*b*
Woody spp.	25.3 (5.4)*a*	7.6 (4.4)*b*	2.0 (0.5)*b*
Total	50.3 (5.0)*a*	36.4 (5.5)*b*	10.1 (1.2)*c*
Phosphorus			
Herbaceous spp.	4.5 (0.7)*a*	4.9 (0.5)*a*	1.3 (0.2)*b*
Woody spp.	3.4 (0.8)*a*	0.9 (0.5)*b*	0.4 (0.1)*b*
Total	7.9 (0.8)*a*	5.8 (0.8)*a*	1.7 (0.2)*b*
Potassium			
Herbaceous spp.	45.4 (7.7)*a*	50.9 (5.9)*a*	11.2 (1.1)*b*
Woody spp.	18.8 (4.2)*a*	4.5 (2.5)*b*	1.9 (0.5)*b*
Total	64.3 (7.0)*a*	55.4 (6.4)*a*	13.1 (1.1)*b*
Calcium			
Herbaceous spp.	20.1 (3.0)*a*	17.9 (3.2)*a*	5.3 (1.4)*b*
Woody spp.	22.7 (6.3)*a*	3.8 (2.2)*b*	2.3 (0.7)*b*
Total	42.8 (6.0)*a*	21.7 (3.6)*b*	7.6 (1.6)*c*
Magnesium			
Herbaceous spp.	4.2 (0.6)*a*	4.3 (0.6)*a*	1.0 (0.2)*b*
Woody spp.	3.5 (0.8)*a*	0.9 (0.5)*b*	0.3 (0.1)*b*
Total	7.7 (0.8)*a*	5.2 (0.7)*a*	1.3 (0.2)*b*

NOTE: Standard errors are given in parentheses. Means in a row followed by the same letter do not differ significantly at the 0.05 level.

with a June maximum and a February minimum (Baker *et al.* 1967).

The stand on the study site was predominately balsam fir and paper birch with scattered red maple (*Acer rubrum* L.), quaking aspen (*Populus tremuloides* Michx.), white spruce (*Picea glauca* (Moench) Voss), and white pine (*Pinus strobus* L.). Total basal area was 19.6 m^2/ha, with balsam fir accounting for 71% and paper birch 15%. There were 949 trees/ha, of which 75% were balsam fir. Average diameter at breast height (dbh) for both balsam fir and paper birch was 15.7 cm. Site index for balsam fir was 18 m (50-year base age). A semiquantitative survey of the area indicated that the composition and density of overstory and the understory were quite uniform throughout the stand.

The site is located on a glacial outwash plain of Omega loamy sand (frigid Spodic Udipsamment). It is an excessively drained soil with low moisture-holding capacity and low organic matter content. The pH of the solum ranges from 4.5 to 5.5 (Soil Conservation Service 1978).

The site was divided into three cutting areas of about 0.8 ha each and an uncut control of about 0.6 ha. The treatments were as follows: whole-tree logging (winter 1974–1975), whole-tree logging (spring 1975), tree-length logging (winter 1974–1975) followed by a prescribed burn (July 1975), and an uncut control. For whole-tree logging, trees are felled and skidded intact to a landing for processing; for tree-length logging, trees are felled, limbed, and topped on site, and then the bole is skidded to the landing (Zasada 1971). The logging operation was a total clear-cut with all stems larger than 2.54 cm dbh felled. The unmerchantable stems were left in place on the site.

On the day of the prescribed fire, the build-up index (a measure of fuel dryness) (Nelson 1964), was high at 26. When the burn was started the humidity was 45%, temperature 31°C, and the wind from the southwest at 19 km/h with gusts to 48 km/h.[4]

[4]Personal communication with Dr. A. Alm, University of Minnesota, Cloquet Forestry Center, Cloquet, MN.

Methods

Field

A 10-m buffer strip was established around clear-cut areas to minimize edge effects. At the end of the second growing season after logging, all aboveground understory vegetation was clipped and collected from 10 randomly located circular plots (0.88 m^2) within each area. The understory was defined as herbaceous plants plus all woody stems less than 2.54 cm dbh. Woody species that commonly reach a height greater than 50 cm (tall shrubs and trees) were separated, but the minor species were bulked. The plots on harvested sites included very few if any plants from the understory which existed prior to logging, because virtually all of it had been destroyed during treatment.

Laboratory

After collection, all vegetation was oven-dried at 65°C and weighed. The material was ground in a Wiley mill to pass a 20-mesh screen, mixed, and a subsample was taken to determine nitrogen by the Kjeldahl method. Another subsample was dry ashed and dissolved in Li–HCl solution. This solution was analyzed on a Jarrel-Ash Direct Reading Spark Emission Spectrograph for concentrations of phosphorus, potassium, calcium, and magnesium. All chemical analyses were done by the Research Analytical Laboratory, Department of Soil Science, University of Minnesota.

Results and discussion

Biomass

There were no significant differences (0.05 level) in understory biomass or nutrients between winter and spring whole-tree logged sites; therefore, the data were combined. After two growing seasons, biomass of herbs and the total understory was significantly greater on all clear-cut areas than on the control (Table 1). The whole-tree logging treatments had more biomass in woody understory species, but on the tree-length logged burn area woody species were at uncut control levels.

Two growing seasons after treatment, the total aboveground biomass on the clear-cut sites, 4181 and 2604 kg/ha for whole-tree logged and tree-length logged burn sites respectively, was only a fraction of the estimated 144 000 kg/ha that was on the area before harvest (Shannon 1976). However, the annual aboveground net primary production (NPP = herbaceous species + woody species leaves + one-half of woody biomass) of 3500 and 2450 kg/ha for the whole-tree logged and tree-length logged burn sites respectively, is near the 3900 kg/ha reported by Baskerville (1965) for a 40-year-old balsam fir stand in New Brunswick, Canada. Thus, it is apparent that the understory vegetation responded quickly to the increase in available resources.

The preharvest survey showed all sites to have very similar understories (Outcalt and White 1981). Alm (1971) has reported no differences in the number or average height of shrubs 2 years after harvest by whole-tree and tree-length logging methods. Thus, the prescribed burn likely decreased the initial understory response on the tree-length logged site by reducing woody species production. This reduction of woody species due to burning has been reported by others (Steen 1966; Buckman 1964; Morris 1970).

TABLE 2. Extra quantity (in kilograms per hectare) of understory nutrients over control levels two growing seasons after treatment

	Treatment	
Component*	Whole-tree logged	Tree-length logged and burned
Nitrogen		
Herbs and shrubs	25.0	18.8
Tree spp.	15.2	7.5
Total	40.2	26.3
Phosphorus		
Herbs and shrubs	4.2	3.2
Tree spp.	2.0	0.9
Total	6.2	4.1
Potassium		
Herbs and shrubs	40.0	37.8
Tree spp.	11.2	4.5
Total	51.2	42.3
Calcium		
Herbs and shrubs	22.1	10.3
Tree spp.	13.1	3.7
Total	35.2	14.0
Magnesium		
Herbs and shrubs	4.5	3.0
Tree spp.	1.9	0.9
Total	6.4	3.9

*Trees are those woody species that commonly grow taller than 1 m. All other woody species were classed as shrubs.

Nutrients

Between treatments, differences in the quantities of understory nutrients corresponded quite closely to differences in biomass. All logged areas contained more N, P, K, Ca, and Mg in herbaceous species and the total understory than did the uncut control (Table 1). There were no differences in the quantities of the five nutrients within woody understory species between the tree-length logged burn treatment and the control. The woody understory species on whole-tree logged sites, however, contained significantly more N, Ca, and Mg than either the tree-length logged burn or control treatments. The tree-length logged burn area also had less total understory N than did the whole-tree logged areas.

Regrowth vegetation can serve as an effective sink for nutrients released by disturbance to forest stands (Ohmann and Grigal 1979). The capture of nutrients by the understory in this study can be calculated as the difference between nutrient quantities on logged and control sites. This is based on the assumption that all sites had the same preharvest understory, as was indicated by the preharvest survey (Outcalt and White 1981).

Although the quantities accumulated (Table 2) are small compared with nutrients contained in the former overstory (10–20%), or in relation to the total nutrient budget of the site, they may be quite significant because about 75% are contained in herbs and shrubs that gradually die back to previous levels as succession continues. Thus, the understory can play a vital part by serving as a "sink" for available nutrients while the next crop of trees is becoming established and gradually releasing them back into the system as the overstory closes and shades out the herbs and shrubs.

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